AN ANTHROPOMETRICAL STUDY OF THE EFFECTS OF GYMNASTIC TRAINING ON AMERICAN WOMEN.

By Claës J. Enebuske, A.M., Ph.D.,
Principal of Instruction in the Boston Normal School of Gymnastics.

In order to trace the results of gymnastic training, the students of the Boston Normal School of Gymnastics are measured at regular intervals during the school year. The first measurements are taken at the beginning of the school work in the autumn; the last measurements are taken at the close of the school in the spring. At the beginning of each month those items which are most susceptible to change under the influence of the training are remeasured, and the change in which has most direct influence upon the working capacity and resistive power of the student, so far as is manifest in gymnasium work. The measures taken each month are the weight, lung capacity, strength of legs, back, chest, left and right forearm. At the beginning and close of the work 53 different measurements are taken in all, namely, the standing height, the length, breadth, depth, girth of various parts of the body, taken at distinct anatomical landmarks. Besides these a series of tracings of the form of the chest are taken at the beginning and close of the year. These are made by means of the anthropometric machines, constructed for this purpose by Démeny in Paris. They consist of, 1st, tracing of thorax in horizontal section, with chest in inspiratory — repose — and expiratory position; 2nd, tracing of the median profile of the trunk with chest in inspiratory, repose, and expiratory position; 3rd, the antero-posterior curve of the back; 4th, the mid spinal line.

In the present paper we wish to present a part of the results attained by the study of the measurements of *one hundred junior students of the school.** The first observation

* The measurements have been made by Miss M. Anna Wood, of Wellesley College, and Miss Margaret S. Wallace, of the Boston Normal School of Gymnastics.

was made before the training began, or in the early part of the training; the second observation was made seven months later. During the intervening period, *i. e.*, from October to May, the students had one hour's gymnastic training five days a week, besides attending the required lectures and recitations. The ages of the students range from seventeen to forty-two years. The distribution of age at the beginning of the training is shown in the following table: —

TABLE I. AGE AT THE FOLLOWING PERCENTILE GRADES.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Years.....	19	19½	20½	21	22	23½	25⅛	27	30	35	37

Height. The highest and lowest statures of these 100 students were 171.3 and 147 centimetres, respectively. Table II shows the distribution of height before and after the training.

TABLE II. HEIGHT.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	151.3	152.8	154.9	156.6	158.6	160.1	160.7	162.7	164.8	167.5	169.5	Centimetre.
After 7 months' training.....	152.0	153.0	155.0	156.8	158.8	160.2	161.5	163.2	166.5	167.6	169.6	

Weight. The highest and lowest weights observed in these cases are, before the training, 74.3 and 40.2 kilos., respectively; after the training, 72.9 and 38.4 kilos., respectively. Table III shows the value of the following percentile grades before and after training: —

TABLE III. WEIGHT.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	43.5	45.0	47.5	49.5	51.5	53.4	55.0	57.5	59.7	63.1	65.8	Kilos.
After 7 months' training.....	43.5	44.8	47.1	49.1	51.7	53.3	55.2	57.3	59.4	62.1	66.4	

It will be seen that a slight diminution in weight has taken place generally (the exceptions being at the 40, 60, and 95 per cent grades).

Lung Capacity. The highest and lowest lung capacity observed in these cases are, before the training, 3.76 and 1.31 litres, respectively; after the training, 4.1 and 1.97 litres, respectively. Table IV shows the value of the following percentile grades: —

TABLE IV. LUNG CAPACITY.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	2.13	2.27	2.40	2.46	2.56	2.65	2.75	2.87	2.95	3.07	3.35	Litre.
After 7 months' training.....	2.27	2.38	2.54	2.65	2.72	2.87	2.96	3.03	3.12	3.29	3.43	

It is seen that increase of lung capacity has taken place at all the percentile grades. After seven months' gymnastic training the value of the 30 per cent grade (2.65) is equal to the value at the 50 per cent grade before the training, and the value at the 50 per cent grade after the training (2.87) is equal to the 70 per cent grade before the training.

Strength of Legs. The extreme values observed are, before the training, 148 and 60 kilos., respectively; after the training, 190 and 81 kilos., respectively. Table V gives the value of the following percentile grades: —

TABLE V. STRENGTH OF LEGS.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	68.0	70.0	78.0	80.0	88.0	93.0	100.0	105.0	119.5	131.5	139.5	Kilos.
After 7 months' training..... ..	87.5	94.5	100.0	108.5	115.0	120.0	127.5	135.0	145.0	160.0	168.5	

Increase has taken place at all the percentile grades. After the training the value at the 10 per cent grade (94.5) is higher than the value of the 50 per cent grade before the

training (93), and the 50 per cent value after the training (120) is higher than the 80 per cent value before the training (119.5).

Strength of Back. The extreme values were, before the training, 100 and 40 kilos., respectively; after the training, 124 and 48 kilos., respectively. Table VI shows the value of the following percentile grades: —

TABLE VI. STRENGTH OF BACK.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	45.5	49.0	52.5	57.5	60.5	65.5	70.0	75.0	80.5	90.0	91.5	Kilos.
After 7 months' training.....	60.0	66.0	72.0	77.0	78.0	81.5	86.0	91.5	95.0	100.0	104.0	

Increase has taken place in all the grades. The 10 per cent value after the training (66) is higher than the 50 per cent value before the training (65.5), while the 50 per cent value after the training (81.5) is higher than the 80 per cent value before the training (80.5), and the 70 per cent value after the training (91.5) is equal to the 95 per cent value before the training.

Strength of Chest. The extreme values before the training were 37 and 15 kilos., respectively; after the training, 48 and 18 kilos., respectively. Table VII shows the value of the following percentile grades: —

TABLE VII. STRENGTH OF CHEST.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	19.0	20.5	24.0	25.0	26.0	27.0	28.0	29.0	30.3	32.8	34.0	Kilos.
After 7 months' training.....	24.5	26.8	28.5	29.8	31.0	32.0	33.0	35.0	36.5	39.0	39.0	

Increase has taken place in all the grades. The 10 per cent value after the training (26.8) is slightly below the 50 per cent value before the training (27), while the 50 per cent

value after the training (32) is higher than the 80 per cent value before the training (30.3), and nearer the 90 per cent value (32.8) before the training.

Strength of Right Forearm. The extreme values were, before the training, 36 and 10 kilos., respectively; after the training, 39 and 19, respectively. Table VIII gives the value of the following percentile grades: —

TABLE VIII. STRENGTH OF RIGHT FOREARM.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	16.0	20.0	22.0	24.0	25.0	26.0	27.0	28.0	30.0	31.5	33.0	Kilos.
After 7 months' training.....	20.0	23.0	24.5	25.0	27.0	28.0	29.0	30.0	32.5	34.5	37.0	

There is increase consequently at all the grades. The 50 per cent value before the training (26) is reached between the 30 and 40 percentile grades after the training, and the 50 per cent value after the training is equal to the 70 per cent value before the training.

Strength of Left Forearm. The extreme values were, before the training, 37 and 9 kilos., respectively; after the training, 38 and 16, respectively. Table IX gives the value of the following percentile grades: —

TABLE IX. STRENGTH OF LEFT FOREARM.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	14.5	16.0	19.0	20.0	21.0	23.0	24.0	25.0	26.0	28.5	30.5	Kilos.
After 7 months' training.....	18.0	19.0	20.5	23.0	24.0	25.0	26.0	27.0	29.0	31.0	33.0	

Increase is found in all grades. The 30 per cent value after the training (23) equals the 50 per cent value before the training, and the 50 per cent value after the training (25) equals the 70 per cent value before the training.

Total Strength. By this term is understood the sum of the five strength tests mentioned. The extreme values

were, before the training, 311 and 156.5 kilos., respectively; after the training, 409 and 202.5 kilos., respectively. Table X gives the value of the following percentile grades: —

TABLE X. TOTAL STRENGTH.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.	Unit.
Before the training.....	176.0	191.0	201.0	213.0	221.0	230.5	243.5	264.0	277.5	293.5	310.0	Kilos.
After 7 months' Training.....	219.0	237.5	254.5	271.0	285.0	293.0	301.5	313.0	325.0	341.0	371.0	

This table shows that the total strength of the 10 per cent grade after the training (237.5) surpasses the 50 per cent grade before the training (230.5), and approaches the 60 per cent grade value (243.5). The 50 per cent value after the training (293) nearly equals the 90 per cent value before the training (293.5), and the 70 per cent value after the training (313) is beyond the 95 per cent value before the training (310).

It is of interest to study the ratio of some of the items mentioned.

Ratio of weight and height, *i. e.*, $\frac{W}{H}$ (W = weight in kilo., H = height in centimetres) expresses how much weight an individual possesses for every centimetre of his stature; for instance, $\frac{W}{H} = 0.340$, *i. e.*, 0.340 kilos. for each centimetre of stature. For the sake of convenience this ratio will be spoken of under the term *weight-height index.* Besides, we present tables indicating the influence of the training upon the following indices: —

Ratio of lung capacity (in litres) and weight $\left(\frac{L\,C}{W}\right)$, *i. e.*, vital capacity-weight index, or, for brevity's sake, *vital index.*

Ratio of total strength (kilos.) and weight $\left(\frac{T\,S}{W}\right)$, *i. e.*, *strength-weight index.*

The product obtained by multiplying vital index by strength-weight index $\left(\frac{L\,C \times T\,S}{W^2}\right)$, *i. e.*, *vital strength-weight index.*

The product obtained by multiplying vital index by total strength $\left(\frac{L\,C \times T\,S}{W}\right)$, *i. e., power index.*

The four indices last mentioned were discussed by the writer in a paper read before the American Association for the Advancement of Physical Education, at its eighth annual meeting in Philadelphia, April, 1892, entitled "Some Measurable results of Swedish Pedogogical Gymnastics," and printed in the proceedings of that Association. To this paper those are referred who are interested in a further description of the indices. Here we will only quote some of the results summed up.

1. The *vital strength-weight index* grows parallel with the growth of efficiency and adaptability to gymnastic exercises; and is indicative of the degree of an individual's training with reference to gymnastic exercises. This index becomes still more instructive in this respect if its component vital index and strength-weight index are consulted also.

2. Under ordinary circumstances those women of vital strength-weight index lower than 0.2000 are not in condition for gymnastic exercises so vigorous as climbing; those of 0.3000 or more are in excellent condition for such exercises; those between 0.2000 and 0.3000 are between unable and well-conditioned.

3. Under ordinary circumstances the *vital index* necessary for ability to climb is in the neighborhood of 0.0474, but in combination with a high strength-weight index or a very energetic moral disposition some imperfect climbing may exist with even lower vital index, and has been observed in a case with as low a vital index as 0.0444.

4. Under ordinary circumstances the *strength-weight* index necessary for ability to climb is about 5.4; but, in combination with high vital index or a very energetic disposition, climbing may be possible with lower strength-weight index, and some imperfect climbing has been observed in a case with strength-weight index only 3.6.

5. Two vital strength-weight indices of equal number may have different values, as exponents of physical efficiency, depending upon whether they are composed of a vital index and a strength-weight index of corresponding heights or of a high and a low index.

6. So far as can be judged from observation of about 100 cases, the vital strength-weight indices of women which correspond to the highest efficiency of the most manifold adaptability in the gymnasium are those composed of a strength-weight index of 6.2 or more, and a vital index of 0.0550 to 0.0600 or somewhat above 0.0600. Those composed of a low strength-weight index and a vital index considerably higher than 0.0600 (0.0650 or more) are more difficult to estimate, and their number is comparatively small.

As an illustration of the correlation between the growth of the vital strength-weight index and the growth of working capacity in the gymnasium the following table is offered. It will be understood without further explanation than to say that the marks are our subjective estimate of the capacity of the students to climb the perpendicular rope. The figures indicate the number of students who have the index as given at the top of the perpendicular column, and the mark in climbing as given at the head of the horizontal column. A^1 means excellence; C, entire inability; B^2, the first struggling success to climb a few inches upward; the other marks indicate the intermediate stages of proficiency.

TABLE XI. Comparison of Vital Strength-Weight Indices and Marks in Climbing of 51 Junior Students of the Boston Normal School of Gymnastics.

	0.1650–0.1999.	0.2000–0.2499.	0.2500–0.2599.	0.2600–0.2699.	0.2700–0.2799.	0.2800–0.2899.	0.2900–0.2999.	0.3000–0.3499.	0.3500–0.3999.	0.4000–0.4499.	0.4500–0.5000.	0.5000–0.5270.	Total.
A^1.....	...	....	....	*3	....	....	....	10	3	3	....	1	20
A^2.. ...	....	*2	....	*1	1	1	2	....	....	....	....	....	7
Ab^1....	....	1	2	1	2	....	....	....	....	....	....	....	6
Ab^2....	....	3	2	....	1	....	....	1	....	....	....	....	7
B^1.....	....	2	....	....	....	....	....	....	....	....	....	....	2
B^2.....	*1	2	1	....	. ..	....	...	....	....	....	....	....	4
C.....	4	....	....	1	....	....	....	....	....	....	....	....	5
Total...	5	10	5	6	4	1	2	11	3	3	....	1	51

Imperfect climbing under difficulty corresponds to index 0.2000–0.2500
Growing ability to climb corresponds to index . . 0.2500–0.3000
Ease in climbing " " " . . 0.3000–0.3500
Great ease in climbing " " " . . 0.3500–

While the vital strength-weight index grows parallel with aptitude in such exercises as demand the weight of the body to be lifted by the individual's own muscles (as climbing, jumping, etc.), the power index shows a more marked correspondence with the growing capacity in such exercises in which outer resistance is combated. It deserves to be noted that the power index, being the product of vital index and total strength, *i. e.*, $\left(\frac{L\,C \times T\,S}{W}\right)$, is also the product of vital strength-weight index and weight, *i. e.*, $\frac{L\,C \times T\,S}{W^2} \times W = \frac{L\,C \times T\,S}{W}$

Weight-Height Index. The extreme values are, before the training, 0.454 and 0.270, respectively; after the training, 0.454 and 0.259, respectively. Table XII gives the value of the following percentile grades: —

TABLE XII. WEIGHT-HEIGHT INDEX.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Before the training.....	0.279	0.290	0.299	0.312	0.322	0.331	0.343	0.351	0.372	0.389	0.401
After 7 months' training.....	0.274	0.286	0.301	0.312	0.320	0.330	0.344	0.351	0.366	0.384	0.405

The general tendency has been towards a slight diminution of this index under the influence of the training.

Vital Index. The extreme values are, before the training, 0.0710 and 0.0307, respectively; after the training, 0.0720 and 0.0409, respectively. Table XIII gives the values of the following percentile grades: —

TABLE XIII. VITAL INDEX.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Before the training.....	0.0384	0.0407	0.0430	0.0456	0.0480	0.0499	0.0513	0.0536	0.0570	0.0602	0.0661
After 7 months' training.....	0.0438	0.0450	0.0475	0.0495	0.0506	0.0530	0.0550	0.0565	0.0590	0.0630	0.0661

Increase of this index has been the general result of the training, except in the highest percentile grades, and the increase has been greatest at the lower grades. The value at the 30 per cent grade after the training (0.0495) approaches the 50 per cent value before the training (0.0499), and the 50 per cent value after the training (0.0530) approaches the 70 per cent value before the training (0.0536).

Strength-Weight Index. The extreme values observed are, before the training, 6.4 and 2.87, respectively; after the training, 7.33 and 3.6, respectively. Table XIV gives the values of the following percentile grades: —

TABLE XIV. STRENGTH-WEIGHT INDEX.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Before the training.....	3.26	3.47	3.72	3.96	4.12	4.40	4.53	4.8	5.27	5.70	5.98
After 7 months' training.....	4.02	4.36	4.77	4.94	5.28	5.48	5.66	6.0	6.35	6.65	7.60

Increase of this index has taken place at all the grades. The value of the 10 per cent grade after the training (4.36) reaches nearly the 50 per cent value before the training (4.40), while the 50 per cent value after the training (5.48) is about equal to the 85 per cent grade before the training.

Vital Strength-Weight Index. The extreme values are, before the training, 0.415 and 0.108, respectively; after the training, 0.527 and 0.166, respectively. Table XV shows the values of the following percentile grades: —

TABLE XV. VITAL STRENGTH-WEIGHT INDEX.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Before the training.....	0.1290	0.1480	0.1710	0.1925	0.2050	0.2180	0.2385	0.2530	0.2730	0.3170	0.3320
After 7 months' training.....	0.1925	0.2150	0.2445	0.2575	0.2690	0.2845	0.3060	0.3325	0.3600	0.3810	0.4100

We find that the value of the 10 per cent grade after the training (0.2150) approaches the 50 per cent value before the training (0.2180), and that the 50 per cent value after

the training (0.2845) is higher than the 80 per cent value before the training (0.2730).

Comparing with the subjective estimate of ability to climb, referred to above, we find that the vital strength-weight index necessary for climbing is —

With difficulty (about 0.2000) before training at 40 per cent, after training at 10 per cent.

Ability (about 0.2500) before training at 70 per cent, after training at 30 per cent.

Ease (about 0.3000) before training at 90 per cent, after training at 60 per cent.

Great ease (about 0.3500) before training at 00 per cent, after training at 75 per cent.

Power Index. The extreme values of this index are, before training, 18.6 and 4.9, respectively; after training, 25 and 9.3, respectively. Table XVI gives the values of the following percentile grades: —

TABLE XVI. POWER INDEX.

Percentile Grade.	5.	10.	20.	30.	40.	50.	60.	70.	80.	90.	95.
Before the training.....	8.10	8.65	9.9	10.35	11.10	11.9	12.45	13.15	13.95	15.10	15.50
After 7 months' training.....	11.05	11.65	13.3	14.10	14.85	15.7	16.40	17.15	17.70	18.95	19.95

The value of the 10 per cent grade (11.65) after the training approaches the 50 per cent value before the training (11.9), while the 50 per cent value after the training (15.7) surpasses the value of the 95 per cent grade before the training (15.5).

The anthropometrical data which we have presented above justify the opinion that the susceptibility of American women to gymnastic training is considerable. The tables of strength and lung capacity, and, still better, the computed indices, the vital strength-weight index, and the power index, show that by seven months' training the mere physical working capacity of these women, such as manifests itself in gymnasium work, has grown from the 10 per cent grade to the 50 per cent grade, and from the 50 per cent grade to the 80 or 90 per cent grade.